Influences of Electrolysis Duration and Voltage Magnitude on Decomposition of HAN Aqueous Solutions

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Abstracts

The objective of this study is to investigate effects of electrolysis durations and voltages on the electrolytic decomposition characteristics in 80 wt.% hydroxylammonium nitrate(HAN) solutions. HAN is a low-toxicity green liquid monopropellant and a potential replacement for hydrazine in space propulsion. However, HAN-based propellants exhibit a relatively high ignition temperature and necessitate the use of high-temperature catalysts due to the elevated reaction temperature. Electrolytic decomposition may offer a solution to these challenges, as it enables self-sustained decomposition starting from ambient temperature and may requires less power compared to thermal catalytic decomposition. In this study, electrolysis durations ranging from 0.25 to 5.0 seconds were tested using 80 wt.% HAN under a pressure of 0.6 MPa. Additionally, voltages ranging from 40 to 60 V were investigated. The reaction process was recorded using high-speed cameras, while the residual liquid was analyzed using FTIR ATR to elucidate the mechanism behind the electrolytic reaction.

Based on the experimental results presented in Figure 1, it was observed that initial vigorous foaming occurred on the anode surface in the HAN solution. This foaming phenomenon is a result of a water electrolysis, and the proton transfer reaction leads to the formation of nitric acid due to the excess concentration of hydrogen ions. Consequently, an autocatalytic reaction of HAN takes place, releasing brown nitrogen oxides gas from the liquid.

In Figure 2, from the experimental group of 0.75 seconds, the temperature change increased obviously, indicating that a self-sustained reaction began to occur. From the Figure 2, it can be observed that as the electrolysis duration increases, there is a tendency for the onset of temperature rise to occur earlier. Clearly, the duration of electrolysis is the crucial factor influencing the induction of self-sustained reaction. According to the experimental results showing the influence of electrolytic voltage depicted in Figure 3, it was noticed that there is an obvious temperature change from the voltage of 50 V, which means that there is an obvious self-sustained reaction. The experimental group with a voltage of 60 V exhibited a slightly earlier onset of temperature rise compared to the experimental group with a voltage of 50 V. This suggests that the voltage increase slightly accelerated the rate of the electrolytic reaction.

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Clearly, voltage is also a key factor affecting the self-sustained reaction. And we know that at 0.6 MPa, the termal decomposition temperature of 80 wt.% HAN aqueous solution is 162 °C. From Figures 2 and 3, the HAN aqueous solution does not reach the termal decomposition temperature of 80 wt.% HAN aqueous solution during the duration of electrolysis, so the electrolytic ignition depends on the electrochemical reaction elicits a subsequent response in self-sustaining reaction, not the Joule effect. And from Figures 2 and 3, we know that the liquid peak temperature of the experimental group that produces the self-sustained reaction falls around 160°C, which is related to the boiling point of water (158°C) at 0.6 MPa, which shows the self-sustained reaction a large part of the energy generated is used for the latent heat of evaporation of water. These findings provide valuable insights for the future design of electrolytic ignition modules for HAN-based propellants, laying a foundation for further research and development.

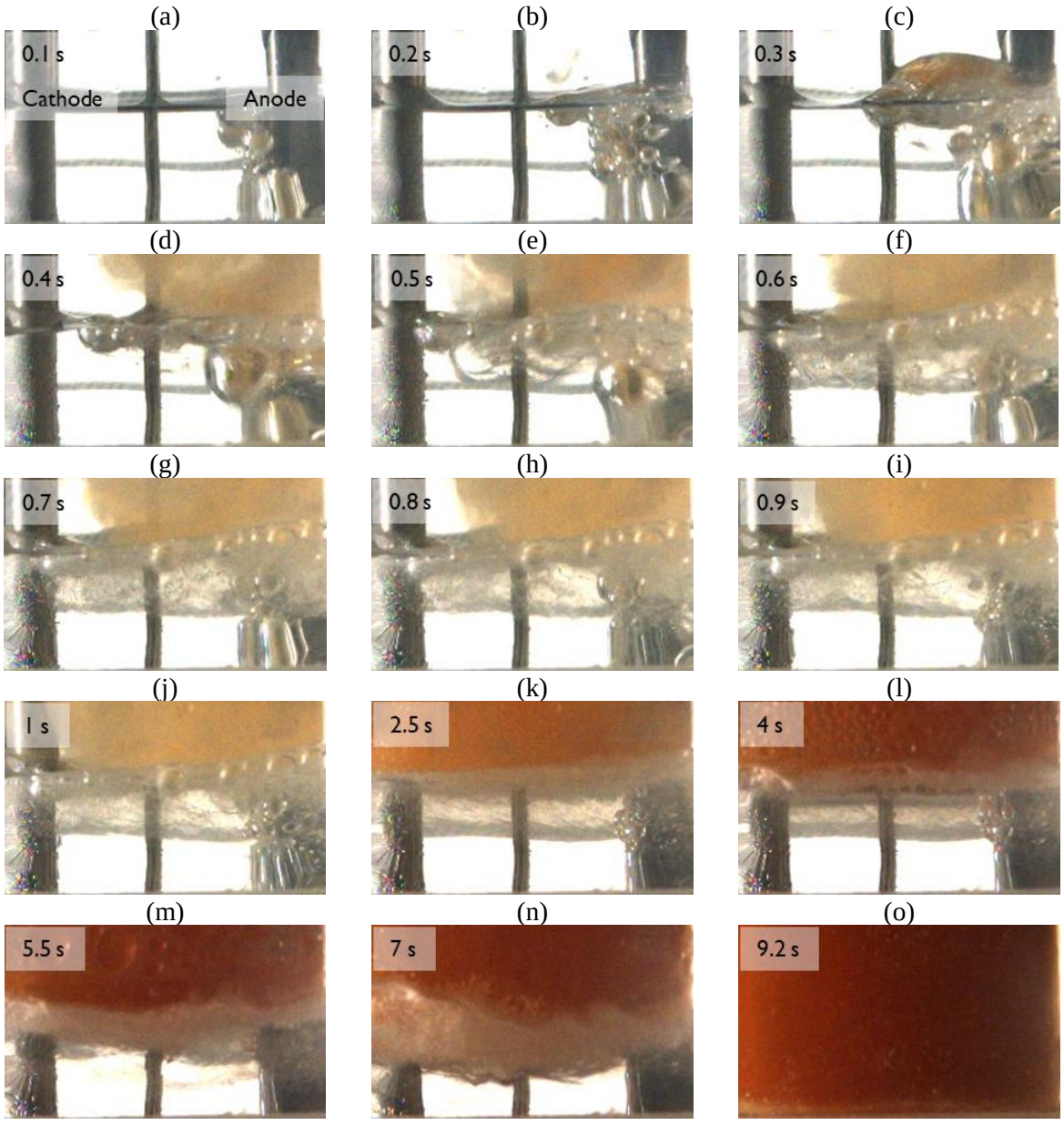

Figure 1: Reaction of time-series image of 80 wt.% HAN aqueous solution under 60 V and 0.6 MPa applied for an electrolysis duration of 0.5 seconds (a)0.1, (b)0.2, (c)0.3, (d)0.4, (e)0.5, (f)0.6, (g)0.7, (h)0.8, (i)0.9, (j)1, (k)2.5, (l)4, (m)5.5, (n)7, (o)9.2 sec.

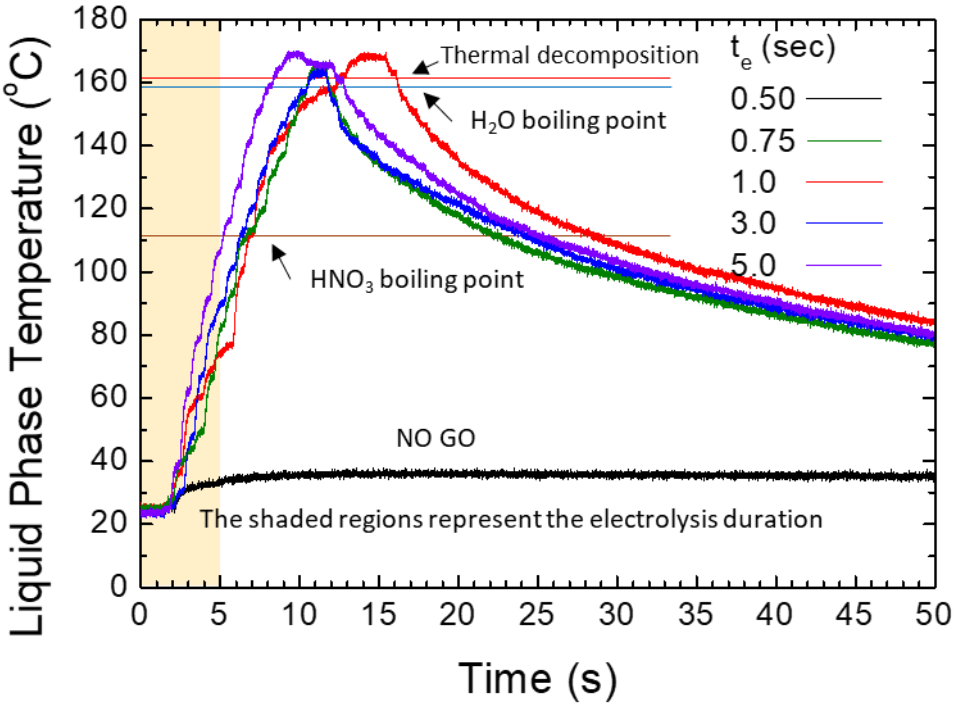

Figure 2: Temperature variation chart of 80 wt.% HAN aqueous solution under 60 V and 0.6 MPa for different electrolysis durations.

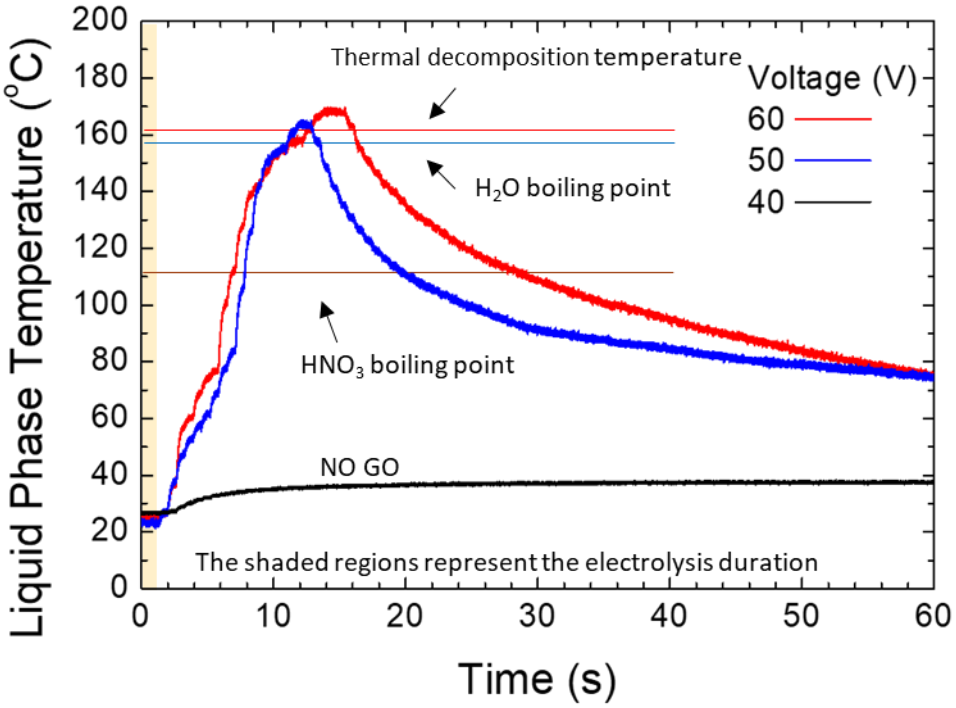

Figure 3: Temperature variation chart of 80 wt.% HAN aqueous solution at 1 seconds electrolysis duration and 0.6 MPa for different voltages.